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# The Upper Mississippi Valley Lead-Zinc District Revisited: Mining History, Geology, Reclamation, and Environmental Issues Thirty Years after the Last Mine Closed

Guidebook for the 2009 Meeting  
of the North-Central Section  
of the Geological Society of America

Rockford, Illinois  
April 2–4, 2009

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## Introduction

This trip is intended to provide a brief introduction to the geology, mining history, cultural history, and related environmental and reclamation issues of the historic lead-zinc mining region of southwestern Wisconsin. The Upper Mississippi Valley mining district, which includes parts of adjacent Iowa and Illinois, is important in the history of economic geology because it is the type area for the class of carbonate-hosted base-metal deposits known as Mississippi Valley-type (MVT) deposits. The district is of significant historical interest because it has been a lead producer since the French explorers first visited the Mississippi Valley in the seventeenth century, and the district was the scene of one of the earliest mineral rushes in the United States, in 1827. The influx of miners in the early nineteenth century ultimately led to Wisconsin becoming a state in 1848. The area continues to be of interest because of ongoing environmental issues, including reclamation and water quality issues related to the widespread metallic mineralization that occurs throughout the region.

Lead production in the district peaked just prior to the Civil War and gradually declined as mining of the deeper zinc deposits increased. Zinc production peaked in the early twentieth century and declined gradually until mining ceased in 1978. Today one has to look hard to find evidence of past mining activity. Many of the carbonate waste rock dumps were used to backfill shafts and declines or were crushed for aggregate. Most mine and mill sites have now been fully or partially reclaimed to the extent that they are no longer recognizable. A rich cultural heritage is preserved in the ethnic traditions of the Cornish, Irish, Italians, and other nationalities that worked the mines and in the many historic buildings that survive in communities such as Shullsburg, Hazel Green, and Mineral Point, Wisconsin, and nearby Galena, Illinois.

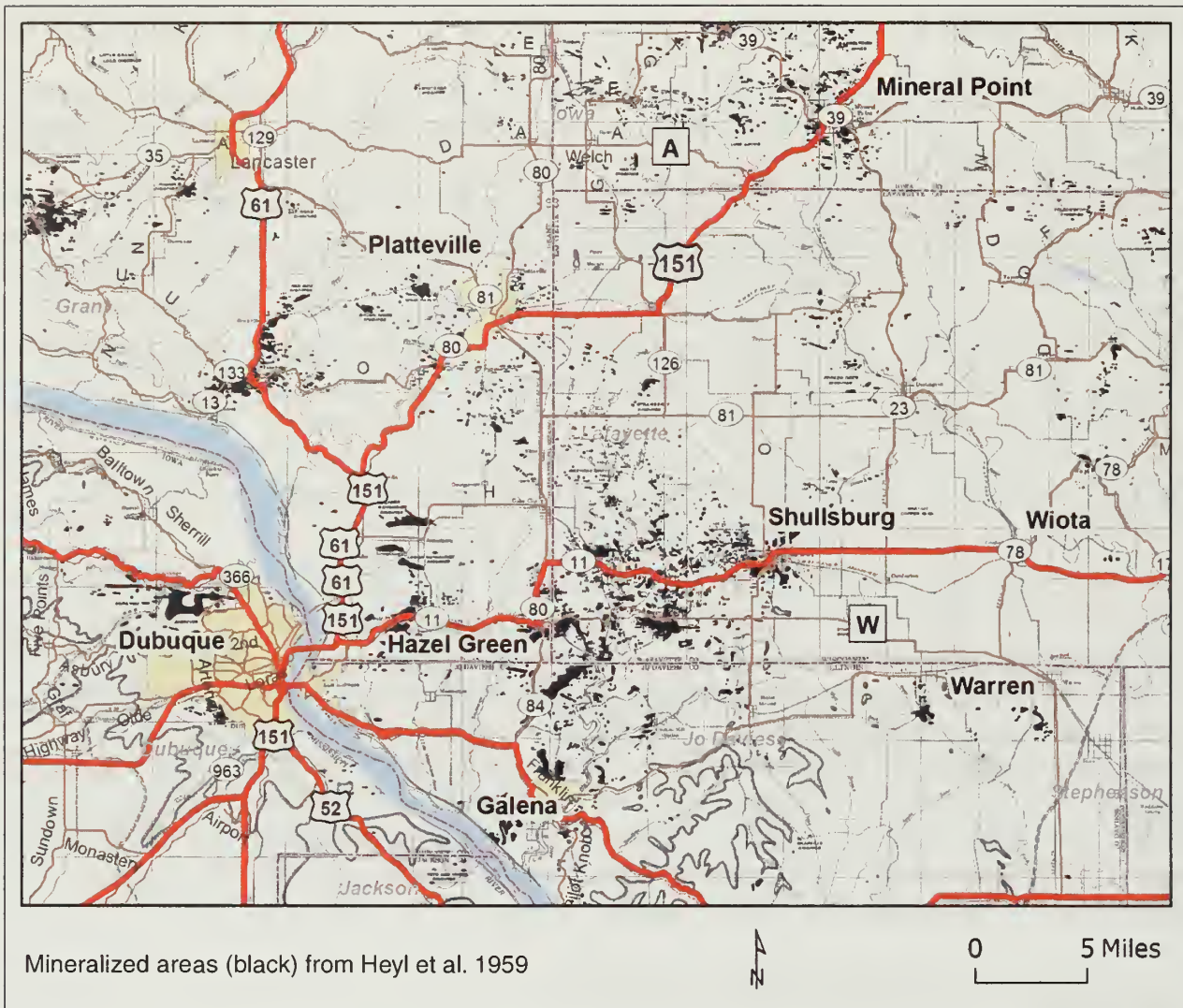
## Geology and Mineral Deposits

The zinc-lead deposits of southwestern Wisconsin, northwestern Illinois, and southeastern Iowa are classic examples of the strata-bound MVT deposits (Figure 1). Many detailed reports and maps have been published about the geology of the area, the most significant and comprehensive of these being the report by Heyl et al. (1959), which describes the regional stratigraphy, mineralization, and structural geology. That publication also documents hundreds of individual deposits and prospects in Wisconsin, Illinois, and Iowa. A good shorter overview is provided by Heyl et al. (1970). This present guidebook does not attempt to provide a scientifically rigorous discussion of the origin of MVT deposits. The interested reader is referred to the publications of Heyl et al. (1959, 1970) and the large body of published literature on MVT base metal deposits.

The ultimate origin of the Upper Mississippi Valley mineral deposits is still debated; some authors favor metal-rich brines migrating out of the Illinois Basin, and others suggest that a component of hydrothermal sources in the Precambrian basement rocks also may be involved. What is definitely known is that the economic mineralization is concentrated in the Middle Ordovician carbonates of the Galena, Decorah, and Platteville formations (Figure 2).

Lead, in the form of the sulfide mineral galena, first attracted miners to the district. The galena occurred in veins and fracture fillings that erosion had exposed at the ground surface. The early miners literally stumbled on the ore at the surface, began to dig it out,





**Figure 1** The Upper Mississippi Valley Lead-Zinc District of southwestern Wisconsin, northeastern Illinois, and southeastern Iowa.

and then followed the mineralized vein along its length and as deep as the ore could easily be mined with primitive tools. Galena mixed with wood or charcoal was burned in crude furnaces to drive off the sulfur, and the lead was cast into ingots for transport. As the “digs” got deeper, a hand-cranked windlass was commonly used to hoist miners and ore to the surface in a bucket. The early shallow “lead digs” did not go below the water table, but later pumps and steam-powered hoists came into use as lead mining reached its peak in the mid-nineteenth century.

Zinc ore, primarily sphalerite and minor amounts of smithsonite, was found below the lead veins and was concentrated in the pitch-and-flat deposits in which the shaly Decorah carbonates were dissolved and replaced by sphalerite, pyrite, and marcasite, along with calcite and/or barite as gangue minerals (Figure 3). The pitches were dipping fractures in the Galena carbonates, formed above the flat deposits, resulting from subsidence caused by dissolution of the Decorah. The pitches were commonly mineralized. The zinc deposits were deeper than the lead veins and required larger-scale mining operations, including high-capacity pumps for dewatering.

The typical zinc mine from the early twentieth century through the 1930s would have had (1) an enclosed headframe built over a two- or three-compartment shaft and (2) a steam-

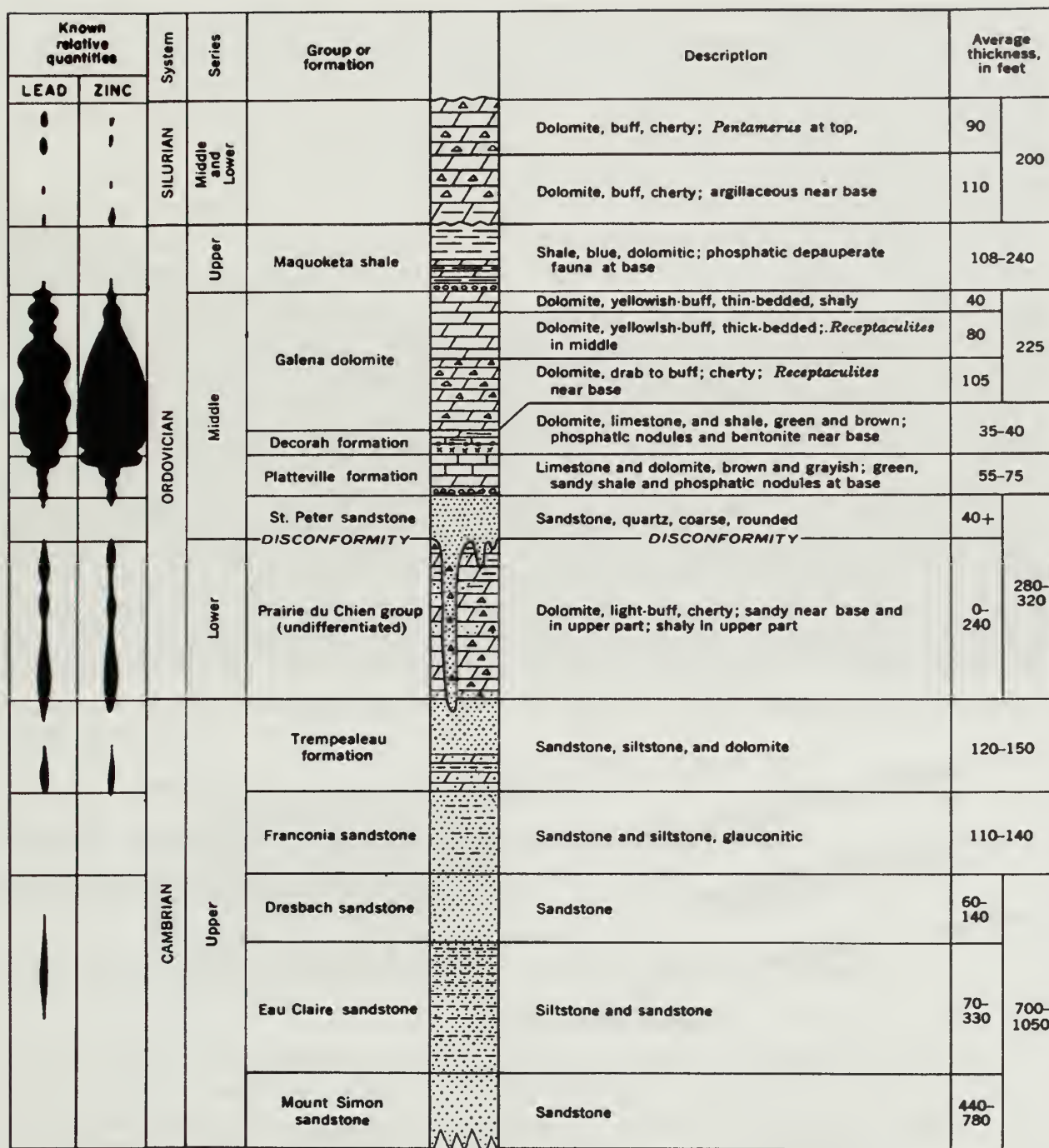


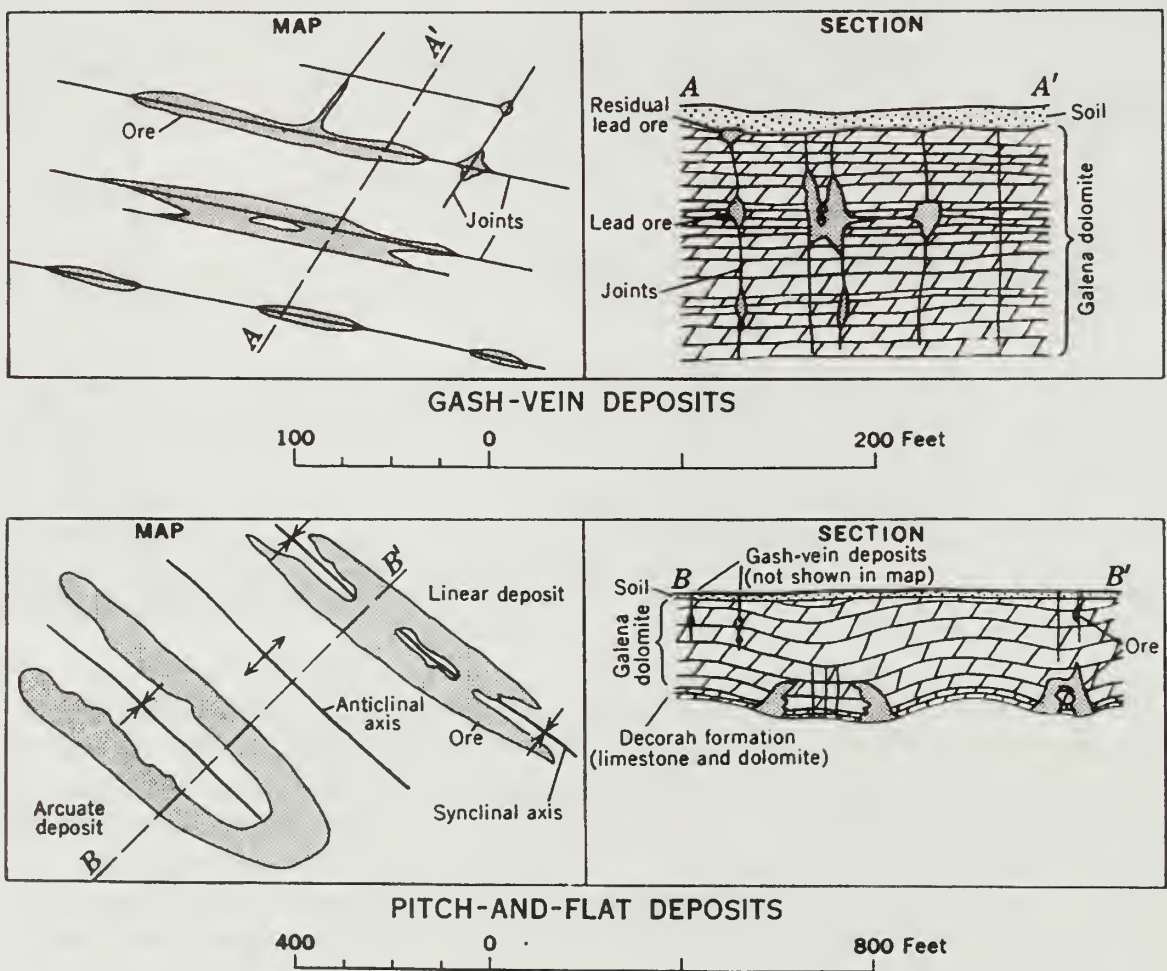
Figure 2 Simplified stratigraphic column for the Upper Mississippi Valley Mining District showing relative position and abundance of lead and zinc minerals (after Heyl et al. 1970).

powered (or later electric-powered) mechanical hoist to bring up the ore. Electric lighting and pneumatic drilling were used along with underground track haulage of ore. Mules pulled the ore cars at first. Later, small gasoline-powered locomotives were used, and we will see an example of these at the Platteville Museum. Ore was commonly presorted underground to avoid hoisting waste rock, which was often used to backfill workings. At the surface, the ore was further sorted, crushed, and concentrated. The early mills used mechanical separation methods such as shaker tables to concentrate the ore, and later mills used the more efficient flotation process. Early "jig tailings" were sometimes reprocessed years later by flotation mills to recover more metal.



From the 1940s to the end of mining in 1978, the number of mines decreased, and the size of operations grew larger and more mechanized. Large mining companies such as Eagle-Picher and New Jersey Zinc initiated aggressive exploration programs, opened new mines, and expanded older mines such as Shullsburg. Hoisting shafts were replaced by inclined shafts, which allowed for truck haulage from the working face to the mill (Figure 4). Adjacent deposits were connected by horizontal drifts, and large complexes such as Shullsburg resulted, where one could drive several miles underground before reaching the extent of the mine workings. A mining company commonly mined ore from several headings in different mines and hauled the ore to a central mill for processing.

The Upper Mississippi Valley Zinc-Lead District extends over five Wisconsin counties as well as Jo Daviess County, Illinois, and a small area of Iowa west of the Mississippi. More than 1.2 million tons of zinc and nearly 100,000 tons of lead were produced from the Wisconsin portion of the District from 1910 to 1974. Heyl et al. (1959) estimated that an additional 250,000 tons of zinc and 350,000 tons of lead were produced from the same area from 1800 to 1910. The District probably contains as much undiscovered ore in the ground as has been mined in the past. Most ore bodies are small (less than 1 million tons), and much of the district has not been thoroughly explored using modern geophysical methods. Some think that, under the right circumstances, the district could again play a role in the mining history of Wisconsin. In reality, the cost of permitting and mining the many small ore bodies would likely prove economically unfeasible for the foreseeable future.



**Figure 3** Diagrammatic plan and section views illustrating typical gash-vein lead deposits and underlying pitch-and-flat zinc-lead deposits (after Heyl et al. 1970).





**Figure 4** *Inclined shaft portal at the Shullsburg mine (circa 1970s). Similar truck access declines replaced vertical shafts during the later years of mining.*

## **Water Supply and Water Quality Issues in Southwestern Wisconsin**

**David M. Johnson, Wisconsin Department of Natural Resources**

The geology of southwestern Wisconsin presents a number of water supply issues that are just now beginning to receive attention. Layers of sandstone alternating with fractured dolomites combined with deeply incised valleys create a complex hydrogeologic system. Several studies document the “stacked” aquifer system, including master’s theses at University of Wisconsin-Madison by Juckem (2003) and Carter (2008). Work by Ken Potter (University of Wisconsin-Madison, unpublished) has documented increasing baseflow to streams throughout the area due to land use changes that have increased recharge, particularly on the side slopes of the valleys.

Extensive agricultural activity has resulted in nitrate and pesticide contamination issues in many areas. The stacked water table conditions, along with large downward gradients and extensive fractures, allow downward movement of pollutants. Wells with shallow casing that are open to multiple aquifers have allowed deep penetration of agriculturally related contaminants. In the three counties we visit on this trip (Lafayette, Grant, and Iowa), at least one pesticide has been detected in 43% of the wells sampled. Seventeen areas encompassing 38,652 acres have been declared atrazine prohibition areas in order to reduce atrazine concentrations in domestic wells to below the health-based

standard of 10 ppm. Nitrate concentrations are above this standard in about 13% of the wells tested and are much higher in certain areas.

Recently, MVT deposits and accompanying low-grade mineralization have been recognized as important factors in determining local water quality. Examples of elevated arsenic and heavy metals contamination are being found in wells across the Driftless Area with increasing frequency. This finding might have been anticipated, given the results of earlier studies (Heyl et al. 1959, Evans and Cieslik 1985, Blabaum et al. 1994). Those researchers reported on the abundance and variety of minerals present in the region that can break down and release metals into the groundwater under appropriate conditions. Unfortunately, until problems with high arsenic concentrations in northeastern Wisconsin groundwater raised concern among regulators and well owners, very few domestic wells were tested for heavy metals.

When the dewatering pumps at the Shullsburg mine complex were shut down in 1978, water levels that had been depressed for mining activities rebounded over a large area. Water quality issues were investigated by the Wisconsin Department of Natural Resources (WDNR), but much of the work focused on increased sulfate concentrations and their effects on dairy herds and production. Although arsenic and several other metals were found at concentrations above the standards of that time in private wells around the mine, the issue was not recognized as a potential regional problem. Within a few years after rebound, the sulfate concentrations began to drop, and no further water quality monitoring was done.

In 1993, Janet Blabaum, of the WDNR, conducted a study looking at abandoned mine sites, waste rock, tailings, and roaster piles and groundwater in the lead-zinc district. Blabaum (1994) found very high concentrations of arsenic, cadmium, chromium, nickel, and zinc in both waste material and leachate from the waste piles. Waters sampled from flooded mines exceeded several groundwater standards (arsenic, 120 ppb; cobalt, 80 ppb; nickel, 210 ppb; and zinc, 3,300 ppb), but no exceedences were found in sampled drinking water sources. Blabaum also compared the results from spring sampling that had been done as part of geochemical prospecting in the region (DeGeoffroy 1969) with the results of ore analysis and found a very high correlation. Blabaum correctly concluded that there was a high potential for metal contamination to ultimately become a problem in domestic water supplies throughout the mineralized region if local conditions were right.

Several case histories follow that provide examples of recently constructed wells that have gone bad because of high concentrations of iron, arsenic, and other metals. Some examples of remediation techniques that have been used with varying degrees of success are included.

1. A private well near Lancaster in Grant County was sampled in 1998 after it developed water quality problems. The lab results were iron, 130 ppm; nickel, 660 ppb; lead, 79 ppb; manganese, 3,200 ppb; zinc, 930 ppb; and aluminum, 2,000 ppb. The well was constructed in 1976 and is typical of most wells in the area. Galena/Platteville carbonates overlie 90 feet of St. Peter Sandstone, and the well bottoms in the Prairie du Chien dolomite. The static water level is near the base of the St. Peter at a depth of 200 feet. The well has a low specific capacity of 0.5 gpm/foot. The long interval of open hole below the casing allows oxygen into the system, creating geochemical instability. The sulfide minerals oxidize and break down, releasing the metals into the well. The well was not sampled for arsenic, which very likely also would have been elevated.



2. Near Fennimore in Grant County, a new private well was drilled up the hill from an old farmstead well. The new well was fine for about six months but then began to experience a dramatic increase in iron concentrations. Treatment became very expensive and difficult, and iron concentrations approached 90 ppm. The arsenic concentration at that time was determined to be 60 ppb. This new well was constructed to the same depth as the old farm well down the hill, which had always had good water. The new well had a very low specific capacity of 0.16 gpm/ft, however, which resulted in more drawdown, allowing more oxygen into the system. Also, the bad well was located on the flank of a mapped anticline, a prime place for mineral deposits. A well was constructed off the structure and has had good water ever since.
3. Three wells near Mineral Point in Iowa County had to be replaced due to arsenic concentrations greater than 130 ppb. Each of these wells had shallow casing with open hole below, allowing water to cascade into the well at times. This aeration triggered the sulfide oxidation reaction that caused the water quality problems.
4. The Village of Wiota in Lafayette County has two municipal wells. One of the wells intersects the St. Peter Sandstone, and the other does not. The well that intersects the St. Peter has had arsenic concentrations as high as 70 ppb. When the operator rotates pumping and limits stress and drawdown on the well that had the high arsenic concentrations, those concentrations can be kept within standards. The other well has slightly elevated barium concentrations, which is common near sulfide deposits, as barite is found as an accessory mineral.
5. A motel near Dodgeville, Iowa County, had aesthetic issues, such as iron staining and odors from water from one of their wells, a good indicator of geochemical instability. Testing indicated that the well had elevated thallium concentrations at 4.8 ppb (standard is 2 ppb). The well was reconstructed with a deeper casing and cement grout, resulting in better aesthetics and thallium concentrations at about 25% of the original levels.
6. Also in the Dodgeville area, a shallow well was recently found to have 24 ppb of antimony, which is four times the standard. The problem was at first thought to be caused by solder and plumbing, but a check of water at the wellhead showed that the antimony was from the shallow well. A new well was drilled with deeper casing and is now producing water with all parameters within standards.

As more wells are constructed in the area, the chances of drilling through or close to a mineralized zone go up. The stress put on the aquifer by excess pumping and drawdown can be an important factor in promoting oxidation when sulfides are present. The move to constant pressure pump systems may help minimize the stress in some cases, but more wells are likely to develop aesthetic issues and ultimately metal levels above standards as more rural residential wells are drilled within the mineralized district. It is now standard procedure to recommend testing private wells for metals as well as bacteria and nitrates.



# Mining and Reclamation History at the Shullsburg Mine Complex

**Thomas C. Hunt, University of Wisconsin-Platteville Reclamation Program**

In 1981, Inspiration Development Company gained ownership of four mines in southwestern Wisconsin from Eagle-Picher Industries. Most of the properties were opened around 1920, except the Shullsburg mine, which was developed during the late 1940s. Permits were acquired under recently enacted Wisconsin mining regulations for all four properties in the mid to late 1970s. Of the four properties, only the Shullsburg and the nearby Bear Hole mines were put into production after they were permitted. The Shullsburg mine and mill site still remains under an active permit with the Wisconsin Department of Natural Resources (WDNR) pending final certification that reclamation is successful and complete.

The Shullsburg mine complex, which is located approximately 3 miles south of Shullsburg, was discovered by Calumet and Hecla Consolidated Copper Company in about 1947. In 1949, the company sunk a 360-foot shaft and began mining several underground ore bodies connected to the hoisting shaft by a series of drifts. The underground workings were extensive and ultimately connected to the Blackstone mine located to the southwest. The ore was processed by an on-site flotation mill (Figure 5). The mill feed ranged between 4 to 6% zinc, primarily as sphalerite. Mining was done below the water table, and a pumping rate ranging from 4 to 17 million gpd was required to dewater the mine workings. During the operating history of the Shullsburg complex, this dewatering created a cone of depression that extended over 12 square miles (Figure 6).

Eagle-Picher acquired the Shullsburg properties in 1954 (Heyl et al. 1959). On April 18, 1978, Eagle-Picher received a permit from the Wisconsin Department of Natural Resources (WDNR) to mine zinc and lead at the Shullsburg mining unit, as required by Wisconsin law. The permit to mine was secured with only an approved reclamation plan. No bond was required because the mine, which had been operating for many years, was permitted as a nonconforming project site. A new mine would have required a more extensive permitting process. The permitted mining site covers 72 acres at the Shullsburg mine and mill and an additional 1 acre at the Blackstone pump site. Although the underground workings underly a much larger area, the reclamation standards apply only to surface workings and processing facilities.

Eagle-Picher operated the Shullsburg mine and mill continuously from 1954 until 1979. The zinc and lead ore was originally hoisted through a two-compartment shaft, but later a decline was constructed so that trucks could haul the ore to the surface, and equipment could be driven directly to the working face. Eagle-Picher extracted about 1,000 tons of ore per day using a modified room-and-pillar mining method and processed about 1,500 tons of ore per day in the flotation mill. The additional ore was hauled by truck from the nearby Bear Hole mine for processing at the mill.

Mining ended permanently in southwestern Wisconsin during 1978–1979. Environmental concerns that were raised in the later years of mining included the temporary lowering of the local water table, polluted surface water discharge, air pollution from diesel exhaust, and blowing dust from tailings piles, stockpiles, and haulage roads. After



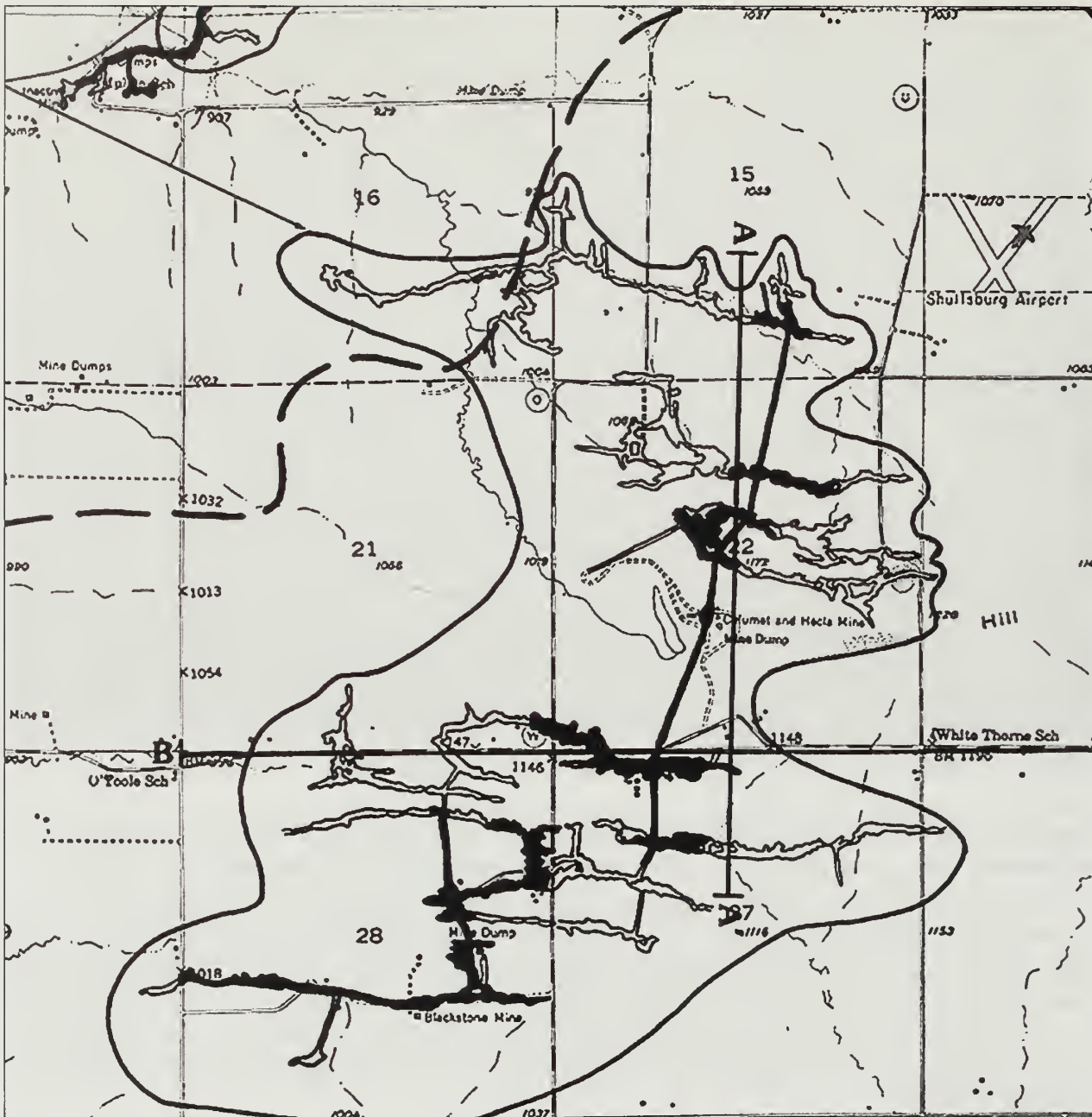
**Figure 5** Overview of the Shullsburg mine and flotation mill site circa 1970s.

the mines closed, most waste piles remained, including flotation tailings, jig tailings, waste rock piles, demolition piles, and junk piles. These waste piles became a concern to local residents and environmental regulators. Waste rock and tailings were partly or completely removed from many mine and mill sites for construction aggregate or agricultural uses. Older sites that were shut down before reclamation rules were enacted often remained unvegetated and littered with debris because they were “grandfathered” and not required to reclaim under terms of a permit as was the Shullsburg complex. Sites where vegetation did establish itself naturally were often overgrazed by cattle, resulting in serious erosion.

Groundwater near the Shullsburg mining complex was contaminated with sulfates soon after dewatering stopped, as described earlier. Around many older mine sites, groundwater and surface water quality is as good or better than ambient water quality, evidence that once the water table rebounds and sulfides are no longer exposed to oxidation, the prime source of contaminants is removed, and groundwater recharge eventually dilutes and flushes the sulfates out of the system. The carbonate host rocks help to neutralize any acidic drainage from surface waste.

Mines were generally not sited in wetland habitat. The proximity of mine sites to perennial streams has not impacted the riparian area appreciably. At Shullsburg and other sites where reclamation has taken place, surface drainage was restored so that runoff water was discharged from the sites without significant erosion. Buildings and foundations that met approved post-mining use criteria remain at a few mine sites. Uses range from farm equipment storage at the Elmo mill to apiary supplies and recreational use (a basketball court). Apart from a minor cave-in at the Bear Hole mining unit, which





**Figure 6** Area of drawdown (cone of depression) caused by dewatering the Shullsburg mine complex.

has been fenced off and appears to be stable, no extensive subsidence or caving has occurred in southwestern Wisconsin. Most zinc mines were deep enough to have 100 feet or more of competent rock above the workings, which has made subsidence a very local and limited problem.

The natural topography of the Shullsburg site was significantly altered by waste piles, steep-sided settling ponds, and relic mine openings and artifacts. This site, like others in the district, was developed before topsoil salvage was required, and generally no topsoil remained for redistribution during reclamation activities. Where topsoil was available from the grading of dikes and berms, it was top-dressed over the site area. Inspiration Development Company routinely used cow manure as a substitute for topsoil in order to promote the establishment of vegetation. The existence of on-site settling ponds has created wetland habitat, albeit small and of marginal value.



The existing vegetation on most former mine sites is introduced agronomic pasture grasses, although existing oak groves at some sites represent a snapshot of pre-settlement vegetation. Pasture grasses and legumes were approved and planted as reclamation species at most sites because the approved post-mining land use was pasture, a use that blends well with the adjacent land use patterns. However, the Shullsburg mining site was designated as wildlife habitat area, a use also compatible with the adjacent land use pattern. Where the land use is recreation or wildlife, such as at the Shullsburg site, native tree and grass species were required in the reclamation plan (Figure 7).

The following chronology places the activities at the Shullsburg mine complex in a historic context:

- 1974 – Wisconsin metallic mining reclamation regulations took effect.
- 1977 – Shullsburg mine applied for a permit to mine.
- 1978 – Shullsburg mine received the required permit.
- 1979 – Shullsburg mine and flotation mill ceased operations due to weak zinc market; sale of waste rock for aggregate (for seal coating) continued.
- 1983 – Mill razed and salvaged.
- 1985 – Portion of tailings pile graded and revegetated.
- 1989 – Removal and sale of waste rock ceased.
- 1995 – Reclamation of remaining portion of site began.
- 2002 – Operator/permittee Terra Industries requested certificate of completion of reclamation; WDNR denied the request due to numerous localized areas that failed to vegetate as a result of sulfuric acid formation (red spots). Permittee responded by recontouring south-facing slope, removing aggressive woody



**Figure 7** View of Shullsburg mine site after reclamation circa 2007.

vegetation that shaded grasses, revegetating slope, and implementing a red spot remediation and monitoring plan.

**2007** – Four-year clock for certificate of completion was extended due to continuation of the red spot problem.

**2008** – Aggressive research to solve red spot problem was initiated (Figure 8).



**Figure 8** Photograph illustrating the red spot problem. The red spots increase in size rather than filling in. Degradation of the vegetation compromises the integrity and stability of the tailings pile. The stress gradient on the vegetation is highlighted by the arrows: the left arrow shows tall robust vegetation; the middle shows thinning, weakened grasses; and the red arrow illustrates the gradient between healthy vegetation and the barren red spot. Photograph by Tom Portle, Wisconsin Department of Natural Resources.

## Reclamation of Zinc Roaster Waste, Mineral Point, Wisconsin

**Thomas C. Hunt, University of Wisconsin-Platteville Reclamation Program**

The type of mineral processing waste that proved to be of greatest immediate environmental concern was zinc roaster waste. The roasting process beneficiated zinc ore to produce zinc oxide concentrate. Because the roasting process was inefficient, large piles of waste accumulated at roasting plant sites (Figure 9). The piles became permanent features of the local landscape because nothing would grow on the material, which contained high levels of iron, sulfur, and toxic heavy metals and leaked acidic, metal-rich effluent to local surface waters.

Roasting at the Mineral Point site began in 1882 and continued until the mid 1930s (Heyl et al. 1959). During operation, the roasters caused acute environmental problems: fumes





*Figure 9* Main zinc roaster waste pile at Mineral Point before reclamation circa 1980.

from the roasters poisoned cattle, killed vegetation, corroded wire fences and screen doors, and poisoned stream water. Several abandoned waste piles were located within the city limits of Mineral Point. Runoff that came in contact with these materials became acidic and was chemically similar to typical acid mine drainage. Runoff was a serious source of contamination to Brewery Creek, which originates north of Mineral Point, runs through it, is about 5 miles in length, and has a gradient of 45 feet/mile. From the point of contact with the roaster waste, Brewery Creek changed from a high-quality stream to a sterile stream classified as marginal waters. The runoff water entering the creek had very low pH (2.1) and high concentrations of heavy metals. During peak runoff, total zinc concentrations in Brewery Creek were 6,600 ppb. Reclamation measures have successfully isolated the roaster waste from the stream, and Brewery Creek now supports fish and aquatic life for its entire length and is very much an asset to the city and area.

In 1987, the WDNR inventoried contaminated sites that were potentially eligible for investigation and cleanup. The Mineral Point Roaster Piles were among the top six sites selected. The site was prioritized for investigation and cleanup, mainly because of the continuing deleterious impacts to Brewery Creek caused by surface runoff and the potential risk of direct human contact with the wastes.

By summer 1989, the WDNR had prepared a scope of work and remedial options plan for the Mineral Point roaster piles. The goal of the plan was long-term stabilization and isolation of the roaster waste and the rehabilitation of Brewery Creek. The stabilization plan placed an emphasis on neutralizing and revegetating the roaster waste piles.

A WDNR Environmental Repair Fund project to combine and cap the roaster piles began in early 1992 and was completed during fall 1993. Waste from several small piles was combined into the largest roaster pile located at the south edge of Mineral Point.





**Figure 10** View of the Mineral Point roaster waste after reclamation circa 2004.

A portion of the highly degraded streambed near the combined pile was filled, a new stream channel was dug, and the stream was diverted to it. Brook trout were stocked in the new stream channel during fall 1993.

Wetlands immediately adjacent the large roaster pile were also degraded by runoff from the pile. The WDNR staff monitored the stream in 1994 to assess conditions, including surface water quality, in-stream habitat, fisheries, stream bottom sediment, and wetlands. During spring 1994, brook trout were still present in Brewery Creek, along with a variety of forage fish. Water quality chemistry parameters had improved, although zinc concentrations were still considered high. Concentrations of heavy metals in stream sediment vary, and in-stream habitat is still poor in some reaches of the Creek, but the piles have been isolated and successfully revegetated (Figure 10). The reclamation work has succeeded in improving general water quality in Brewery Creek and in isolating the highly toxic roaster waste.

## **Constructing a Modern Four-Lane Highway through an Old Mining District**

**Bruce A. Brown Wisconsin Geological and Natural History Survey, and  
Daniel D. Reid, Wisconsin Department of Transportation**

The reconstruction of U.S. 151 between Dodgeville and Dickeyville, Wisconsin, transformed a winding two-lane road into a modern freeway. The new highway bypassed cities and towns and required extensive cut and fill to establish an entirely new grade and alignment. A concern raised during the initial design stage was whether the cuts would intersect historic mine workings or whether there would be shallow workings below the grade that could result in collapse or subsidence.

Fortunately, much of the area had been mapped at the scale of 1:24,000 by the U.S. Geological Survey (USGS) as part of a series of investigations in the mining district. The Mineral Development Atlas, a cooperative effort of the Wisconsin Geological and Natural History Survey (WGNHS), USGS, and the Bureau of Mines had resulted in compilation of mining company maps showing the underground workings of most of the post-1900 zinc mines. The early nineteenth century lead mines and digs were less well documented, but most mines had been located, and areas of digs had been plotted on the 1:24,000 maps.

The atlas was very detailed, plotted on large sheets of drafting linen at a scale of 1:2,400 (1 map inch represents 200 feet). Each sheet had to be individually copied because the atlas existed only as hard copy. Thanks to the Wisconsin Department of Transportation, the atlas was disassembled and scanned, and the images were georeferenced by Mike Czechanski (WGNHS). This effort resulted in bringing the detailed mapping of the atlas into a digital Geographic Information Systems (GIS) environment and an overlay of the mine maps on the proposed highway alignment, using current aerial orthophotography as a base.

Fortunately, much of the proposed alignment, from near the Iowa-Lafayette County line, past Belmont and Platteville to Dickeyville, appeared to miss all known zinc mine workings. The area around Mineral Point proved to be a potential problem. No zinc mines were located under the alignment, but extensive areas of lead digs, an indicator of mineralization and rock alteration, were mapped in the area west of the fairgrounds, the site of a large cut on the new bypass. The lack of mapped mine workings suggested that no special design modifications would be required. Immediately after grading began, equipment operators reported finding galena, and the rock surface was crossed with numerous calcite and barite veins. As construction of the fairgrounds cut proceeded, it became evident that rock quality in the mineralized zone was not sufficient to support nearly vertical cuts (Figure 11). After the cut was completed, rock began to fall from the mineralized zone, and it was decided to cut the face back to a much shallower slope (Figure 12). This remediation cost a significant amount of money and prompted a careful look at the atlas maps for potential future problems.



**Figure 11** U.S. Highway 151 fairgrounds road cut under construction in 2001.





**Figure 12** Fairgrounds cut after modification circa 2003.



**Figure 13** U.S. Highway 151, County A cut circa 2003.



Another area of mineralization indicated by lead digs and a small zinc prospect was identified at the junction of U.S. 151 and County A near the Lafayette County line. This cut was redesigned with a cutback vegetated slope to avoid the problems at the fairgrounds cut (Figure 13), and it has performed well since. The modified design was incorporated prior to bidding the contract and saved the taxpayers the cost of remediation. No significant mining or mineralization problems were encountered south of County A.

## **Stop Descriptions**

### **Stop 1: Shullsburg Mine and Mill Site Reclamation**

Most people driving by the Shullsburg Mine and mill site would never realize that this location was once the site of a large mine and mill complex, complete with a decline shaft, tailings, waste piles, mill buildings, and settling basins (Figure 5). Today the 72-acre site has been reclaimed as wildlife habitat. As described earlier, the reclamation of this site involved regrading and reshaping a large amount of tailings and a major cleanup of the site to remove buildings and equipment, properly seal the shaft and decline, and establish vegetation. Haulage and access roads were removed, and the site drainage was designed to minimize erosion of the fine tailings material, which proved a challenge to revegetate because of residual acidity. The effort has been largely successful, with a few problems such as the “red spot” problem left to be worked out before the WDNR will consider reclamation complete and permanent.

### **Stop 2: Badger Lead Mine and Shullsburg Mining and Historical Museum**

The Badger Mine and Museum, located in the Shullsburg city park, provide an opportunity to enter an actual early crevice lead mine that operated from 1827 until 1854. Miners worked in near darkness, with candles for light, and dug out the galena ore with hand tools and, when necessary, blasted with black powder. The workings that are accessible to visitors represent only a small portion of the mine tunnels that exist under the city, most of which are unmapped, as are most of the early lead mines throughout the district. There is not much mineralization left to see, as the early miners were quite efficient. One can, however, get a good idea of the claustrophobic working conditions by looking into the narrow side tunnels. The museum on the surface has some excellent exhibits of mining tools, mineral samples, and mine models that illustrate early mining methods.

### **Stop 3: Historic Mine Sites and “Natural Reclamation” Examples between Shullsburg and Platteville**

We will travel west from Shullsburg along County W in Lafayette County and, as time permits, stop briefly to look at historic mine sites typical of what can still be found in the district. In most cases, jig and flotation tailings never completely revegetated without some soil conditioning, and a few small areas remain where old piles are severely eroded. Most of the zinc roasting waste has been removed or isolated, and examples of polluted surface water are very rare. The last large mine building remaining in the area is

the New Jersey Zinc mill at Elmo, which is visible on the east side of Highway 80 north of Cuba City. The buildings now house a farm implement dealer. We will also have the opportunity along the way to see several historic buildings dating from the early mining era.

#### **Stop 4: Platteville Mining Museum**

The Platteville Mining Museum consists of a collection of mining relics, a reconstructed headframe and hoist, an operating mine railroad, and an excellent underground exhibit in an 1845 lead mine. The underground exhibits illustrate both an early crevice lead mine similar to the Badger Mine at Shullsburg and a twentieth century mechanized zinc mine, similar to what the Eagle-Picher Shullsburg mine would have looked like. Dioramas and an extensive collection of mining equipment and tools illustrate the mining process. On the surface, there is a museum building that houses mineral collections and mining displays. Outdoor exhibits include the railroad; a variety of trucks, hoists, and other equipment; and the mine headframe building, complete with operating hoist and shaft. Other exhibits illustrate how ore was sorted and processed.

#### **Stop 5: Road Cut Design Modification in Mineralization Areas, U.S. 151**

The carbonate rocks of the Galena and Platteville formations have a good track record for stability in nearly vertical road cuts. Alteration associated with mineralization can make the otherwise hard dolostones soft and easily eroded. As time permits, we will stop at the County A cut and/or the Mineral Point fairgrounds cut, both of which required significant design modification to stabilize. The fairgrounds cut provides a good cross section of a flat deposit, showing thinning typical of the Decorah formation and extensive sulfide mineralization. Evidence of mineralization is visible in both cuts at the ends of the cutback areas, suggesting that perhaps the areas should have been extended to remove all of the sulfide-containing rock, which is now beginning to weather and decrepitate, causing maintenance issues.

#### **Stop 6: Zinc Roaster Waste Reclamation and Historic Buildings—Mineral Point, Wisconsin**

We will drive through the old mining town of Mineral Point on our way to view the roaster waste reclamation site. Many buildings still remain from the mining era, including some houses that date from the early nineteenth century. Unfortunately, we will not have time to visit Pendarvis State Historic Site, a museum containing several restored buildings, a lead mine site, and a look at the life of the early Cornish miners. We will proceed to the south end of town, past the zinc roaster site and former acid plant site to view the reclaimed roaster waste pile and the restored Brewery Creek.

## References

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